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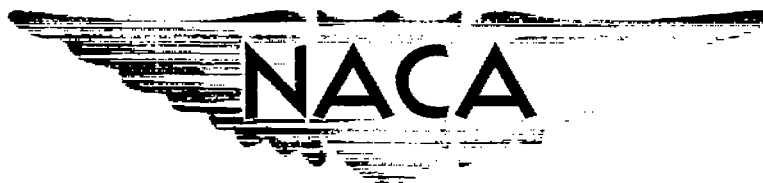
RESEARCH MEMORANDUM

EXPLORATORY INVESTIGATION OF THE EFFECT OF

SKEWED PLAIN NOSE FLAPS ON THE LOW-SPEED

CHARACTERISTICS OF A LARGE-SCALE

TRIANGULAR-WING-FUSELAGE MODEL

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RESEARCH MEMORANDUM

EXPLORATORY INVESTIGATION OF THE EFFECT OF SKEWED PLAIN NOSE

FLAPS ON THE LOW-SPEED CHARACTERISTICS OF A LARGE-SCALE

TRIANGULAR-WING-FUSELAGE MODEL

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SUMMARY

An investigation of the effect of skewed plain nose flaps on a thin, low-aspect-ratio triangular wing in combination with a high fineness-ratio fuselage has been conducted at low speeds and high Reynolds numbers. The plan form of the flaps was such that the flap chord varied from zero percent of the wing chord at the model center line to 100 percent at about 91-percent wing semispan. Lift, drag, and pitching-moment data were obtained over an angle-of-attack range of -2° to 30° at zero sideslip. The Reynolds numbers of the investigation were 12.5 and 14.1 million (based on the wing mean aerodynamic chord of 16.37 ft).

The results of the investigation indicated that the nose flaps provided a significant delay in the occurrence of both the leading-edge type of separation and tip stalling. The delay was indicated by the degree of adherence of the experimental to the theoretical (unseparated flow) variation of drag coefficient with lift coefficient. With the nose flaps deflected, the flow separation occurred at a lift coefficient of about 0.35, compared to approximately 0.1 for the plain wing. The maximum reduction in drag due to the delay was approximately 25 percent at lift coefficients between 0.4 and 0.5. The changes in the lift and pitching-moment characteristics were less significant. In view of the favorable results obtained from this exploratory investigation, it is believed that further research on the effect of skewed plain nose flaps on thin, low-aspect-ratio triangular wings is desirable.

INTRODUCTION

The thin triangular wing of low aspect ratio has been found to have several undesirable aerodynamic characteristics at low speed (reference 1). The majority of these undesirable characteristics were attributable to extensive and early flow separation at the leading edge and to an early tip stall.

The attempts made thus far to improve the characteristics have been concerned with alleviating only the effects of the leading—edge separation and have not proved very successful. (See references 1 and 2.) Further consideration of the problem, however, has indicated the desirability of finding methods which will alleviate the effects of both types of flow separation. One method which is thought to be promising is to use plain nose flaps of such a plan form that the ratio of flap chord to wing chord increases with increasing distance out along the span. With this skewed type of flap plan form, deflection of the flaps should be similar in effect to twisting the wing, in that downward flap deflection would wash out the tip sections and thereby delay tip stalling. The purpose of the investigation reported herein was to determine whether such a nose—flap arrangement does, in fact, have the anticipated effect on the flow separation.

SYMBOLS AND COEFFICIENTS

The symbols and coefficients used in this report are defined as follows:

A aspect ratio $\left(\dfrac{b^2}{S}\right)$

α free—stream angle of attack of wing chord plane, degrees

b wing span, measured normal to wing center line, feet

c wing chord, measured parallel to wing center line, feet

$\bar{c}$ wing mean aerodynamic chord $\left(\dfrac{\int_0^{b/2} c^2\, dy}{\int_0^{b/2} c\, dy}\right)$, measured parallel to wing center line, feet

C_L lift coefficient $\left(\dfrac{\text{lift}}{qS}\right)$

C_D drag coefficient $\left(\dfrac{\text{drag}}{qS}\right)$

C_{D_o} drag coefficient of plain wing—body combination at zero lift

C_m pitching—moment coefficient $\left(\dfrac{\text{pitching moment}}{qS\bar{c}}\right)$

δ_f nose—flap deflection measured with reference to wing chord plane in a plane normal to the hinge line, degrees

q free—stream dynamic pressure, pounds per square foot

S   wing plan–form area (includes area covered by body), square feet

y   spanwise distance measured perpendicular to wing center line, feet

MODEL AND APPARATUS

The investigation was conducted in the Ames 40– by 80–foot wind
tunnel. The model used in the investigation was a triangular–wing–
fuselage combination previously used in the tests which were reported
in reference 3. Because the investigation was exploratory in nature,
approximate rather than actual skewed plain nose flaps were used on
the model. The pertinent dimensions and construction details of the
flaps can be seen in figures 1 and 2 which are, respectively, a three–
view drawing and a photograph of the model.

A significant feature of the flaps is that the ratio of flap chord
to wing chord increased with increasing distance along the span. At the
wing center line the flap chord was zero percent of the wing chord and
increased to 100 percent at about 91–percent semispan. While the type
of variation was chosen for aerodynamic reasons, the exact magnitude was
necessarily fixed by the structure of the model and was smaller than con-
sidered desirable. It should also be noted that the upper–surface con-
tour of the flaps was curved rather than flat like the similar portion
of the basic airfoil section which was a double wedge that had been modi-
fied by rounding the nose (0.0025c radius) and the maximum thickness
ridges. (This choice of upper–surface contour was made on the basis of
the theoretical indication that the subsonic–type airfoil section is
preferable at low supersonic as well as at subsonic speeds.) A constant–
percent–chord nose radius was approximated by using a series of tubes
which decreased in size toward the tip.

TESTS AND RESULTS

Lift, drag, and pitching–moment data were obtained for an angle–of–
attack range of –2° to 30° at zero sideslip. Two nose–flap deflections
were investigated, 40° and 60°. The Reynolds number of the tests was
14.1 million (based on $\bar{c}$) up to 24° angle of attack, and 12.5 million
above.

The plan–form dimensions used in reducing the test results to coeffi-
cient form are given in figure 1. Corrections for wind–tunnel–wall effects
and support–strut interference were applied to the data.

The test results are presented in figures 3 and 4 (C_L vs C_D in
fig. 3, C_L vs α and C_m in fig. 4). The data for the wing–fuselage
combination without the nose flaps, denoted in the figures as the plain–
wing configuration, were obtained from reference 3.

DISCUSSION

Presented in figure 3 along with the experimental variations of drag coefficient with lift coefficient are two theoretical variations. One of the theoretical drag curves $[(C_{D_O} + (C_L^2/\pi A)]$ is for the condition of unseparated flow and the theoretical elliptic loading; the other $(C_{D_O} + C_L \tan \alpha)$ is for a condition of completely separated flow such that the resultant force (neglecting skin friction) is normal to the chord plane.[1] These two theoretical curves are useful in establishing the effectiveness of the nose flaps in reducing the flow separation. Any changes in the positions of the measured drag curves relative to the theoretical curves are indicative of the relative amounts of flow separation, other conditions being equal.

It is apparent from the drag curves of figure 3, therefore, that the nose flaps were effective in reducing the flow separation. They were most effective in the lift—coefficient range from about 0.15 to 0.35. In this range, the curve for either flap deflection is similar in shape to the unseparated—flow curve and lies closer to it than does that for the plain—wing condition. Above a lift coefficient of 0.35, the curve for either flap deflection approaches the plain—wing curve which lies close to and has essentially the same shape as that for separated flow. (The divergence of the curves for the two flap deflections, from the unseparated—flow drag curve in the lift—coefficient range below 0.15, is believed to be due to a lower—surface flow separation caused by the downwardly deflected nose flaps.)

The relative positions of the curves are not entirely indicative of the relative amounts of flow separation, since the nose flaps might also have changed the induced drag[2] and the skin—friction drag. Both of these changes, in contrast to a change due to flow separation, would be expected to show only a slight variation with lift coefficient, at least in the low lift—coefficient range. Therefore, since each of the nose—flap drag variations have nearly the same shape as that for unseparated flow in the lift—coefficient range from about 0.15 to 0.35, it is believed that flow separation was nearly eliminated by the nose flaps in this lift—coefficient range. Computations based on an effective wing twist indicated that the offset of the drag curve for the 40° deflection, from the unseparated—flow curve, can be mainly attributed to an induced drag change; the remainder was probably due to an increase in skin—friction drag. The difference between the results for the 40° and 60° deflections

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[1]For both curves, the experimental zero—lift—drag coefficient for the plain—wing condition has been assumed to be representative of the skin—friction drag.

[2]See reference 4, from which it can be determined that tip washout will produce an induced drag increment that is nearly constant with lift coefficient.

in this lift—coefficient range of 0.15 to 0.35 is attributable to an induced drag change.

Since pressure—distribution measurements on the plain wing—fuselage model (reference 3) showed evidence of leading—edge separation over the outboard 10 percent of the span at a lift coefficient of 0.1, complete stall of this portion of the span at a lift coefficient of 0.2 and com—plete stall over the outboard 25 percent of the span at a lift of 0.35, it can be concluded that the nose flaps delayed the occurrence of both types of flow separation. Part of this favorable effect of the nose flaps can be attributed to their upper—surface contour. Unpublished results of tests of a triangular wing with an NACA 0005 airfoil section indicate the probable maximum magnitude of the contour effect. These results indicated that flow separation was absent up to a lift coeffi—cient of 0.2; whereas it was absent up to 0.1 for the present plain—wing model and 0.35 for the present model with nose flaps deflected. Thus, at least 0.15 of the 0.25 lift—coefficient increment due to the nose flaps was the result of the deflection of the nose flaps.

Although the major concern of the investigation was with regard to changes in flow separation, the magnitude of the changes in the drag, lift, and pitching—moment characteristics are worth noting. The drag characteristics showed the most change due to nose—flap deflection; the maximum percentage change was approximately a 25—percent reduction at lift coefficients between 0.4 and 0.5 ($\delta_f = 40^\circ$).[3] In the case of the lift characteristics (fig. 4), the nose flaps had a slightly unfavorable effect. There was a reduction in lift for a given angle of attack due to a positive shift in the angle—of—zero lift (as would be expected with washout of the tip sections) and a reduction in the lift—curve slope. This latter effect of the change in flow separation is not uncommon for low—aspect—ratio wings of triangular plan form (e.g., see references 2 and 5). In contrast to the drag and lift characteristics, the pitching—moment characteristics (fig. 4) were insignificantly affected.

CONCLUDING REMARKS

On the basis of the results presented herein, it is concluded that the nose flaps delayed the occurrence of both leading—edge flow

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[3]With regard to the drag of a low—aspect—ratio triangular wing, it is important to note that twisting the wing results in an increase in the induced drag, the flat wing having the minimum induced drag by virtue of its elliptic span loading. Therefore, in considering the use of wing twist, the existing amount of separation drag to be reduced by the twist must be weighed against the increase in induced drag. For the present model, it is apparent that the reduction in separation drag out—weighed the increase in induced drag.

separation and tip stalling in the low lift—coefficient range and reduced
the amount of flow separation in the upper lift—coefficient range. In
view of the favorable effect on the flow separation, it is believed that
further research, using a more refined flap installation, is desirable.

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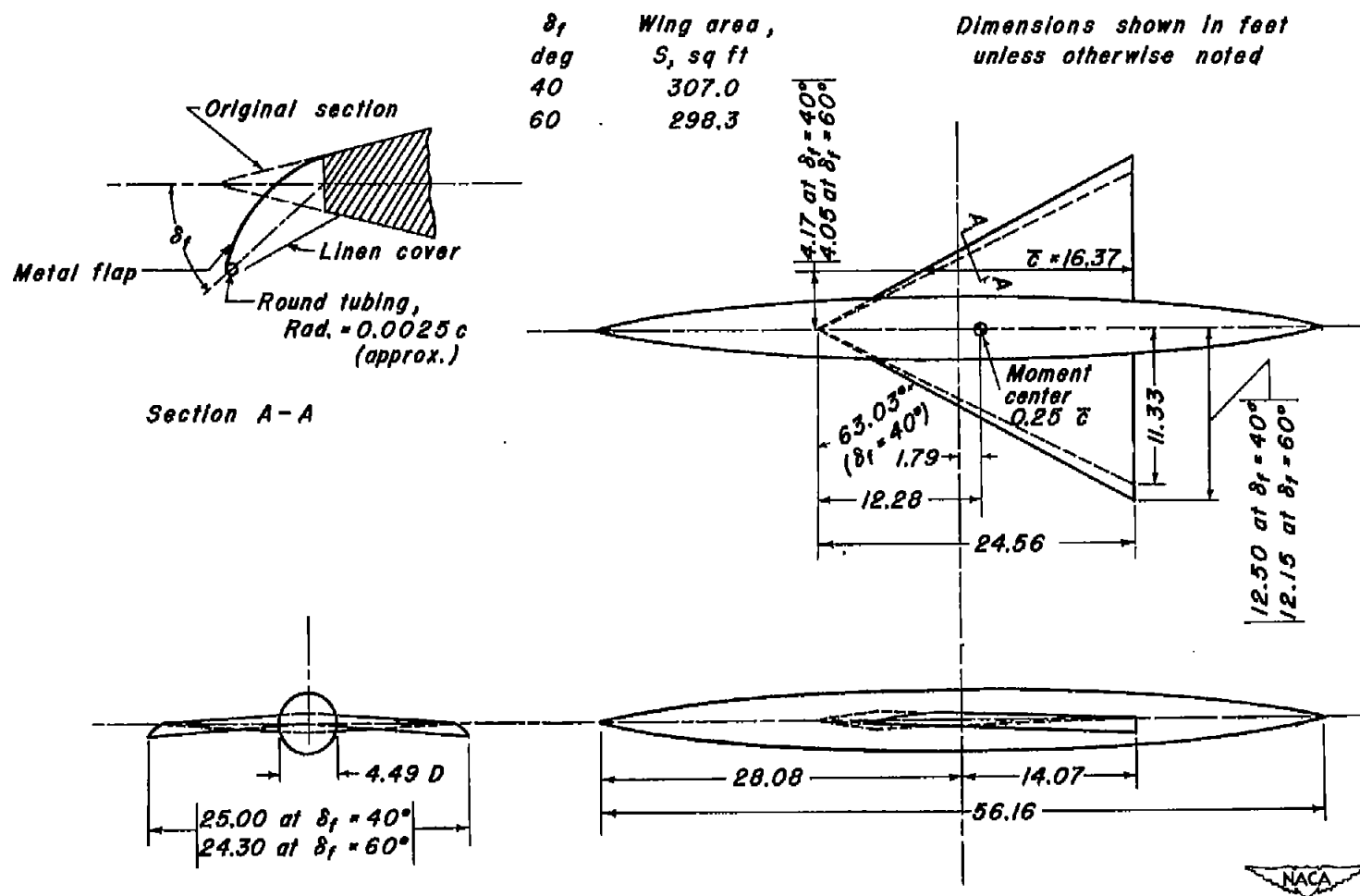   L6K20, 1947.

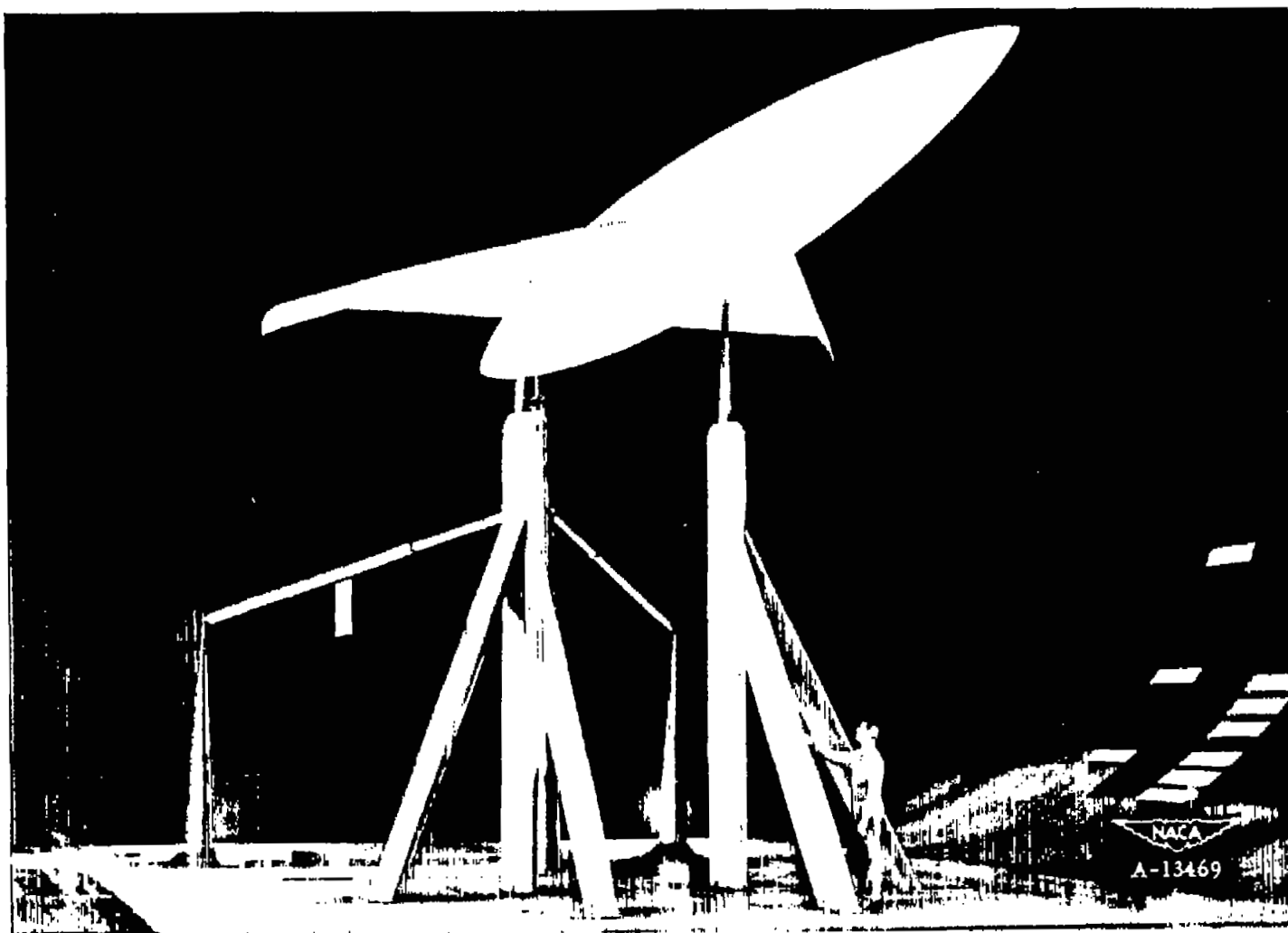Figure 1.— General arrangement of the model tested.

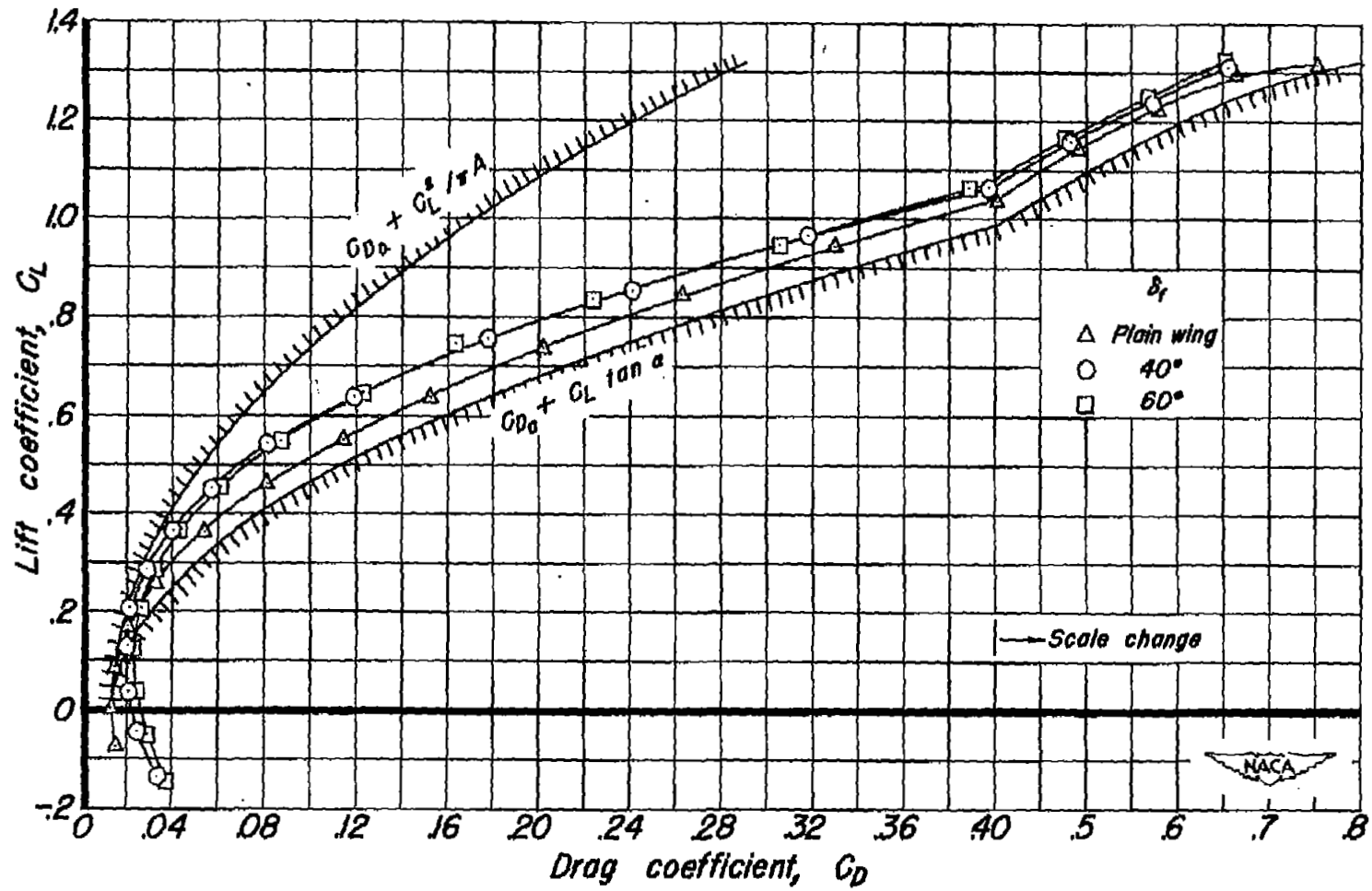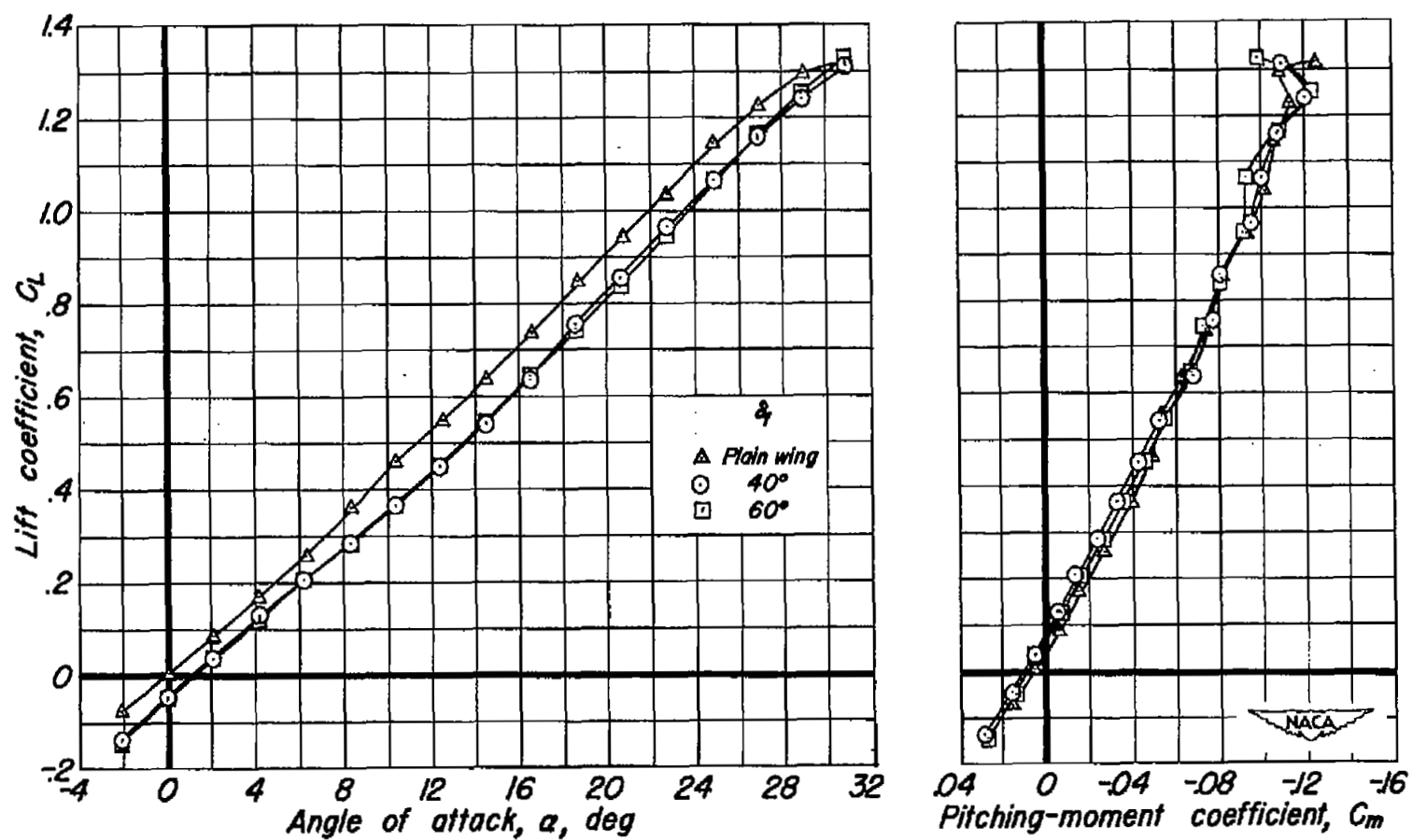Figure 2.— Triangular wing-fuselage combination mounted in the Ames 40- by 80-foot wind tunnel.

Figure 3. - Drag curves.

Figure 4.— Lift and pitching-moment curves.